1. Given the reaction for the corrosion of aluminum:

$$4\,Al + 3\,O_2 \rightarrow 2\,Al_2O_3$$
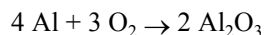
Which half-reaction correctly represents the oxidation that occurs?
1) $Al + 3e^- \rightarrow Al^{3+}$
2) $Al \rightarrow Al^{3+} + 3e^-$
3) $O_2 + 4e^- \rightarrow 2\,O^{2-}$
4) $O_2 \rightarrow 2\,O^{2-} + 4e^-$

2. Given the reaction:
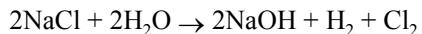
$Cu(s) + 4HNO_3(aq) \rightarrow$
$$Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(\ell)$$
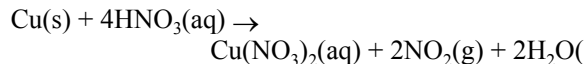
As the reaction occurs, what happens to copper?
1) It undergoes reduction and its oxidation number decreases.
2) It undergoes reduction and its oxidation number increases.
3) It undergoes oxidation and its oxidation number decreases.
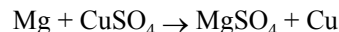4) It undergoes oxidation and its oxidation, number increases.

3. Given the reaction:
$$2NaCl + 2H_2O \rightarrow 2NaOH + H_2 + Cl_2$$
Which electronic equation correctly represents the oxidation that occurs in this reaction?
1) $2Na^0 \rightarrow 2Na^+ + 2e^-$
2) $2Cl^- \rightarrow Cl_2{}^0 + 2e^-$
3) $2H^+ + 2e^- \rightarrow H_2{}^0$
4) $O_2{}^0 + 2e^- \rightarrow 2O^{-2}$

4. Given the reaction:
$$Mg + CuSO_4 \rightarrow MgSO_4 + Cu$$
Which equation represents the oxidation that takes place?
1) $Mg^{2+} + 2e^- \rightarrow Mg$ 3) $Cu^{2+} + 2e^- \rightarrow Cu$
2) $Mg \rightarrow Mg^{2+} + 2e^-$ 4) $Cu \rightarrow Cu^{2+} + 2e^-$
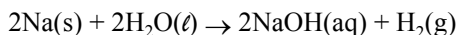
5. Given the reaction:
$$2Na(s) + 2H_2O(\ell) \rightarrow 2NaOH(aq) + H_2(g)$$
What substance undergoes oxidation?
1) Na
2) NaOH
3) H_2
4) H_2O
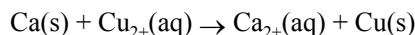
6. Given the reaction:
$$Ca(s) + Cu_{2+}(aq) \rightarrow Ca_{2+}(aq) + Cu(s)$$
What is the correct reduction half-reaction?
1) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
2) $Cu^{2+}(aq) \rightarrow Cu(s) + 2e^-$
3) $Cu(s) + 2e^- \rightarrow Cu^{2+}(aq)$
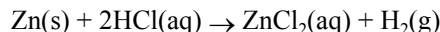4) $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$
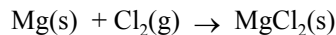
7. Given the reaction:
$$Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$$
Which half-reaction correctly represents the reduction that occurs?
1) $Mg(s) + 2e^- \rightarrow Mg^{2+}$
2) $Cl_2(g) + 2e^- \rightarrow 2Cl^-$
3) $Mg^{2+} \rightarrow Mg(s) + 2e^-$
4) $2Cl^- \rightarrow Cl_2 + 2e^-$

8. Which half-reaction correctly represents reduction?
1) $Ag \rightarrow Ag^+ + e^-$
2) $F_2 \rightarrow 2F^- + 2e^-$
3) $Au^{3+} + 3e^- \rightarrow Au$
4) $Fe^{2+} + e^- \rightarrow Fe^{3+}$

9. Given the reaction:
$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$
Which equation represents the correct oxidation half-reaction?
1) $Zn(s) \rightarrow Zn^{2+} + 2e^-$
2) $2H + 2e^- \rightarrow H_2(g)$
3) $Zn^{2+} + 2e \rightarrow Zn(s)$
4) $2Cl^- \rightarrow Cl_2(g) + 2e^-$
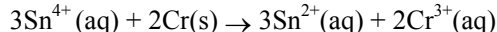
10. Given the reaction:
$$3Sn^{4+}(aq) + 2Cr(s) \rightarrow 3Sn^{2+}(aq) + 2Cr^{3+}(aq)$$
Which half-reaction correctly represents the reduction that occurs?
1) $Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$
2) $Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2e^-$
3) $Cr(s) \rightarrow Cr^{3+}(aq) + 3e^-$
4) $Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$

11. In the reaction
$$Mg + Cl_2 \rightarrow MgCl_2,$$
the correct half-reaction for the oxidation that occurs is
1) $Mg + 2e^- \rightarrow Mg^{2+}$
2) $Cl_2 + 2e^- \rightarrow 2Cl^-$
3) $Mg \rightarrow Mg^{2+} + 2e^-$
4) $Cl_2 \rightarrow 2Cl^- + 2e^-$

12. Given the nickel-cadmium battery reaction:

$$2NiOOH + Cd + 2H_2O \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftharpoons}} 2Ni(OH)_2 + Cd(OH)_2$$

During the discharge of the battery, Ni^{3+} ions are
1) reduced, and cadmium metal is reduced
2) reduced, and cadmium metal is oxidized
3) oxidized, and cadmium metal is reduced
4) oxidized, and cadmium metal is oxidized

Base your answers to questions **13** and **14** on the reaction below

$$2Cr(s) + 3Cu^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 3Cu(s)$$

13. The electronic equation that represents the oxidation reaction that occurs is
1) $2Cr^0 - 6e^- \rightarrow 2Cr^{3+}$ 3) $2Cr^{3+} - 6e^- \rightarrow 2Cr^0$

2) $2Cr^0 + 6e^- \rightarrow 2Cr^{3+}$ 4) $2Cr^{3+} + 6e^- \rightarrow 2Cr^0$

14. If 3 moles of Cu react according to the equation above, the total number of moles of electrons transferred will be
1) 1   3) 3
2) 2   4) 6

---

15. Given the equation:

$$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$$

Which species undergoes reduction?
1) C(s)
2) H^+
3) C^{2+}
4) $H_2(g)$

16. Given the reaction:
    $Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$
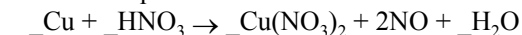Which half-reaction correctly shows the oxidation that occurs?
1) $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
2) $Fe(s) + 2e^- \rightarrow Fe^{2+}(aq)$
3) $Cu^{2+}(aq) \rightarrow Cu(s) + 2e^-$
4) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

17. Given the reaction:
    $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$
Which half-cell reaction represents the reduction that occurs?
1) $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$
2) $Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$
3) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
4) $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

18. Given the equation:

$$2\,Al + 3\,Cu^{2+} \rightarrow 2\,Al^{3+} + 3\,Cu$$

The reduction half-reaction is
1) $Al \rightarrow Al^{3+} + 3e^-$ 3) $Al + 3e^- \rightarrow Al^{3+}$
2) $Cu^{2+} + 2e^- \rightarrow Cu$ 4) $Cu^{2+} \rightarrow Cu + 2e^-$

19. Given the reaction:
    $2Al^0(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni^0(s)$
What is the total number of moles of electrons lost by 2 moles of $Al^0(s)$?
1) 6   3) 3
2) 2   4) 8

20. Given the cell reaction:
    $Sn(s) + Pb^{2+}(aq) \rightarrow Sn^{2+}(aq) + Pb(s)$
The reduction half-reaction for this cell is
1) $Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ 3) $Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$
2) $Pb(s) \rightarrow Pb^{2+}(aq) + 2e^-$ 4) $Sn(s) \rightarrow Sn^{2+}(aq) + 2e^-$

21. Given the equation:
    $3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$
What is the total number of moles of electrons lost by the copper as it completely reacts with 8 moles of nitric acid?
1) 1   3) 8
2) 6   4) 4

22. When the equation
    $\_Pb^{2+} + \_Au^{3+} \rightarrow \_Pb^{4+} + \_Au$
is correctly balanced using the smallest whole number coefficients, the coefficient of the Pb^{2+} will be
1) 1   3) 3
2) 2   4) 4

23. Given the unbalanced equation which represents aluminum metal reacting with an acid:
    $Al + H^+ \rightarrow Al^{3+} + H_2$
What is the total number of moles of electrons lost by 1 mole of aluminum?
1) 6   3) 3
2) 2   4) 13

24. The net ionic equation
    $Fe(s) + Pb^{2+}(aq) \rightarrow Fe^{2+}(aq) + Pb(s)$
illustrates conservation of
1) mass and charge   3) mass but not charge
2) charge but not mass   4) neither mass nor charge

25. Given the reaction:

$2Cr(s) + \_Sn^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + \_Sn(s)$

When the reaction is correctly balanced using the smallest whole numbers, the coefficient of $Sn^{2+}(aq)$ is

1) 1   3) 3
2) 2   4) 4

26. Given the balanced equation:

$3Fe^{3+}(aq) + Al(s) \rightarrow 3Fe^{2+}(aq) + Al^{3+}(aq)$

What is the total number of moles of electrons lost by 2 moles of Al(s)?

1) 1 mole   3) 3 moles
2) 6 moles   4) 9 moles

27. Which redox equation is correctly balanced?

1) $Cr(s) + 3Fe^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + Fe(s)$
2) $Pb(s) + 2H^{+}(aq) \rightarrow Pb^{2+}(aq) + H_2(g)$
3) $Pb(s) + Ag^{+}(aq) \rightarrow Pb^{2+}(aq) + Ag(s)$
4) $Zn(s) + Br_2(aq) \rightarrow Zn^{2+}(aq) + Br^{-}(aq)$

28. Given the reaction:

$\_Mg + \_Cr^{3+} \rightarrow \_Mg^{2+} + \_Cr$

When the equation is correctly balanced using smallest whole numbers, the sum of the coefficients will be

1) 10   3) 5
2) 7   4) 4

29. When the redox reaction below is completely balanced using the smallest whole numbers what is the coefficient of NO?

$\_Ag + \_HNO_3 \rightarrow \_AgNO_3 + \_NO + \_2H_2O$

1) 1   3) 3
2) 2   4) 4

30. Given the reaction:

$\_Hg^{2+} + \_Ag \rightarrow \_Hg + \_Ag^{+}$

When the equation is completely balanced using the smallest whole number coefficients, the coefficient of Hg will be

1) 1   3) 3
2) 2   4) 4

31. Given the unbalanced equation:

$\_\_Br_2 + \_\_Sn \rightarrow \_\_Br^{-} + \_\_Sn^{2+}$

When the equation is correctly balanced using the smallest whole-number coefficients, the coefficient of Br^{-} is

1) 1   3) 3
2) 2   4) 4

32. Given the unbalanced equation:

$\_\_\_Ag_2S + 8HNO_3 \rightarrow$
$\_\_\_AgNO_3 + 2NO + \_\_\_S + \_\_\_H_2O$

What is the coefficient of Ag_2S when the equation is completely balanced using the smallest whole numbers?

1) 6   3) 3
2) 2   4) 4

33. When the redox equation

$\_Cr^{3+}(aq) + 3Mn(s) \rightarrow \_Mn^{2+}(aq) + \_Cr(s)$

is completely balanced, the coefficient of $Cr^{3+}(aq)$ will be

1) 1   3) 3
2) 2   4) 4

34. Given the reaction:

$\_\_Cl_2(g) + \_\_Fe^{2+}(aq) \rightarrow \_\_Fe^{3+}(aq) + \_\_Cl^{-}(aq)$

When the equation is correctly balanced using *smallest* whole numbers, the coefficient of $Cl^{-}(aq)$ will be

1) 1   3) 6
2) 2   4) 7

35. What is the coefficient of H^{+} when the redox equation below is correctly balanced with whole number coefficients?

$Cr_2O_7^{2-} + 6I^{-} + \_H^{+} \rightarrow Cr^{3+} + H_2O + 3I_2$

1) 14   3) 7
2) 2   4) 12

36. Given the equation:

$\_KMnO_4 + \_HCl \rightarrow$
$\_KCl + \_MnCl_2 + \_Cl_2 + \_H_2O$

What is the coefficient of H_2O when the equation is correctly balanced?

1) 8   3) 16
2) 2   4) 4

37. When the equation

$\_Al + 3NO_3^{-} + \_H^{+} \rightarrow \_Al^{3+} + 3H_2O + 3NO_2$

is completely balanced, the coefficient of Al will be

1) 1   3) 3
2) 2   4) 4

38. Given the reaction:

$\_Cr^{3+} + 10OH^{-} + \_ClO_3^{-} \rightarrow \_CrO_4^{2-} + \_Cl^{-} + 5H_2O$

When the reaction is completely balanced using the smallest whole numbers, the coefficient of Cr^{3+} will be

1) 1   3) 3
2) 2   4) 4

39. Given the unbalanced equation:

$H_2S + HNO_3 \rightarrow S + NO + H_2O$

What is the coefficient of the H_2S when the equation is correctly balanced using whole numbers?

1) 5   3) 3
2) 2   4) 4

40. Given the reaction:

$\_HNO_3 + \_H_3PO_3 \rightarrow \_NO + \_H_3PO_4 + \_H_2O$

When the reaction is completely balanced using the smallest whole numbers, the coefficient of H_3PO_4 will be

1) 1   3) 3
2) 2   4) 4

41. Given the unbalanced equation:

$\_NO_3^{-} + 4H^{+} + \_Pb \rightarrow \_Pb^{2+} + \_NO_2 + 2H_2O$

What is the coefficient of NO_2 when the equation is correctly balanced?

1) 1   3) 3
2) 2   4) 4

42. What is the coefficient of Fe^{2+} when the redox equation below is correctly balanced?

$\_Fe^{2+} + \_NO_3^{-} + \_H^{+} \rightarrow \_Fe^{3+} + \_NO + 2H_2O$

1) 1   3) 3
2) 2   4) 4

43. Which redox equation is correctly balanced?
    1) $Al + 2H^+ \rightarrow Al^{3+} + H_2$
    2) $Zn + 2H^+ \rightarrow Zn^{2+} + H_2$
    3) $Cr + Ag^+ \rightarrow Cr^{3+} + Ag$
    4) $Cu + Ag^+ \rightarrow Cu^{2+} + Ag$

44. When the equation
    $\_Cu + \_HNO_3 \rightarrow \_Cu(NO_3)_2 + 2NO + \_H_2O$
    is completely balanced using whole numbers, the coefficient of the HNO_3 will be
    1) 8   3) 6
    2) 2   4) 4

45. Which redox reaction is balanced?
    1) $Fe^{3+} + 2Ni \rightarrow Fe^{2+} + 2Ni^{2+}$
    2) $2Fe^{3+} + Ni \rightarrow 2Fe^{2+} + Ni^{2+}$
    3) $Fe^{3+} + Ni \rightarrow Fe^{2+} + Ni^{2+}$
    4) $3Fe^{3+} + 2Ni \rightarrow 3Fe^{2+} + 2Ni^{2+}$
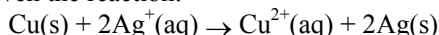
46. Given the reaction:
    $Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$
    Which statement correctly indicates the electron change that occurs?
    1) One mole of $Cu(s)$ loses a total of 2 moles of electrons.
    2) One mole of $Cu(s)$ gains a total of 1 mole of electrons.
    3) Two moles of $Ag^+(aq)$ loses a total of 2 moles of electrons.
    4) Two moles of $Ag^+(aq)$ gains a total of 1 mole of electrons.
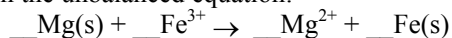
47. Given the unbalanced equation:
    $\_Mg(s) + \_Fe^{3+} \rightarrow \_Mg^{2+} + \_Fe(s)$
    When the equation is completely balanced using smallest whole numbers, the coefficient of $Mg(s)$ will be
    1) 1   3) 3
    2) 2   4) 4

48. Given the unbalanced equation:
    $\_Fe + \_Ag^+ \rightarrow \_Ag + \_Fe^{3+}$
    When the equation is correctly balanced using smallest whole numbers, the coefficient of Ag^+ is
    1) 5   3) 3
    2) 2   4) 4
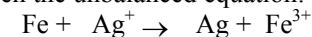
49. Given the above unbalanced equation:
    $2MnO_4^- + 16H^+ + \_Cl^- \rightarrow 2Mn^{2+} + 8H_2O + \_Cl_2$
    What is the coefficient in front of the Cl^- when the equation is completely balanced using whole numbers?
    1) 1   3) 5
    2) 2   4) 10
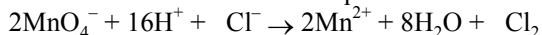
50. Given the balanced reaction:
    $2Al(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2(g)$
    What is the total number of electrons gained by $H^+(aq)$ when 2 moles of $Al(s)$ is completely reacted?
    1) 6   3) 3
    2) 2   4) 12
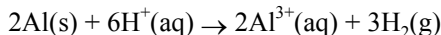
51. Given the balanced equation:
    $2Al(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2(g)$
    When 2 moles of $Al(s)$ completely reacts, what is the total number of moles of electrons transferred from $Al(s)$ to $H^+(aq)$?
    1) 5   3) 3
    2) 6   4) 4
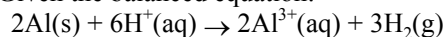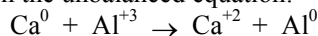
52. Given the unbalanced equation:
    $Ca^0 + Al^{+3} \rightarrow Ca^{+2} + Al^0$
    When the equation is completely balanced with the smallest whole number coefficients, what is the coefficient of Ca^0?
    1) 1   3) 3
    2) 2   4) 4

53. Given the equation:
    $2Al(s) + 3Cu^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Cu(s)$
    The total number of moles of electrons transferred from $2Al(s)$ to $Cu^{2+}(aq)$ is
    1) 9   3) 3
    2) 2   4) 6
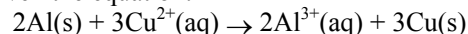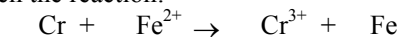
54. Given the reaction:
    $\_Cr + \_Fe^{2+} \rightarrow \_Cr^{3+} + \_Fe$
    When the reaction is completely balanced using the smallest whole number coefficients, the sum of the coefficients is
    1) 10   3) 3
    2) 6   4) 4

55. Given the unbalanced equation:
    $Cr^0 + Sn^{2+} \rightarrow Cr^{3+} + Sn^0$
    What is the coefficient in front of the Cr^{3+} when the equation is balanced using smallest whole number coefficients?
    1) 1   3) 3
    2) 2   4) 6
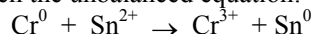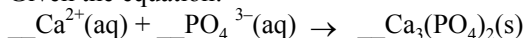
56. Given the equation:
    $\_Ca^{2+}(aq) + \_PO_4^{3-}(aq) \rightarrow \_Ca_3(PO_4)_2(s)$
    When the equation is correctly balanced, the sum of the total charge of the reactants is
    1) 0   3) −3
    2) +2   4) +6

57. Given the unbalanced equation:
    $\_MnO_2 + \_HCl \rightarrow \_MnCl_2 + \_H_2O + \_Cl_2$
    When the equation is correctly balanced using smallest whole number coefficients, the coefficient of HCl is
    1) 1   3) 3
    2) 2   4) 4

58. Which equation shows conservation of both mass and charge?
    1) $Cl_2 + Br^- \rightarrow Cl^- + Br_2$
    2) $Cu + 2 Ag^+ \rightarrow Cu^{2+} + Ag$
    3) $Zn + Cr^{3+} \rightarrow Zn^{2+} + Cr$
    4) $Ni + Pb^{2+} \rightarrow Ni^{2+} + Pb$

59. Given the unbalanced equation:

$$\_IO_3^- + 4H_2O + \_SO_2 \rightarrow \_I_2 + \_SO_4^{2-} + 8H^+$$
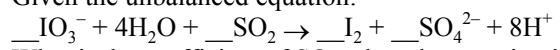
What is the coefficient of SO_2 when the equation is correctly balanced?

1) 1

2) 2

3) 5

4) 8

Reference Tables

Table N
Selected Radioisotopes

Nuclide	Half-Life	Decay Mode	Nuclide Name
^{198}Au	2.69 d	β^-	gold-198
^{14}C	5730 y	β^-	carbon-14
^{37}Ca	175 ms	β^+	calcium-37
^{60}Co	5.26 y	β^-	cobalt-60
^{137}Cs	30.23 y	β^-	cesium-137
^{53}Fe	8.51 min	β^+	iron-53
^{220}Fr	27.5 s	α	francium-220
^{3}H	12.26 y	β^-	hydrogen-3
^{131}I	8.07 d	β^-	iodine-131
^{37}K	1.23 s	β^+	potassium-37
^{42}K	12.4 h	β^-	potassium-42
^{85}Kr	10.76 y	β^-	krypton-85
^{16}N	7.2 s	β^-	nitrogen-16
^{19}Ne	17.2 s	β^+	neon-19
^{32}P	14.3 d	β^-	phosphorus-32
^{239}Pu	2.44×10^4 y	α	plutonium-239
^{226}Ra	1600 y	α	radium-226
^{222}Rn	3.82 d	α	radon-222
^{90}Sr	28.1 y	β^-	strontium-90
^{99}Tc	2.13×10^5 y	β^-	technetium-99
^{232}Th	1.4×10^{10} y	α	thorium-232
^{233}U	1.62×10^5 y	α	uranium-233
^{235}U	7.1×10^8 y	α	uranium-235
^{238}U	4.51×10^9 y	α	uranium-238

ms = milliseconds; s = seconds; min = minutes;
h = hours; d = days; y = years

Answer Key

1.   2

2.   4

3.   2

4.   2

5.   1

6.   1

7.   2

8.   3

9.   1

10.   1

11.   3

12.   2

13.   1

14.   4

15.   2

16.   1

17.   3

18.   2

19.   1

20.   1

21.   2

22.   3

23.   3

24.   1

25.   3

26.   2

27.   2

28.   1

29.   1

30.   1

31.   2

32.   3

33.   2

34.   2

35.   1

36.   1

37.   1

38.   2

39.   3

40.   3

41.   2

42.   3

43.   2

44.   1

45.   2

46.   1

47.   3

48.   3

49.   3

50.   1

51.   2

52.   3

53.   4

54.   1

55.   2

56.   1

57.   4

58.   4

59.   3